ARS 42-114
March 1966

UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Research Service

RADIANT ENERGY DISTRIBUTION OF THREE GAS-FIRED INFRARED CHICK BROODERS

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The brooding phase of broiler production is probably the most critical period in the life of the chicken. The temperature regulating mechanism of the young bird is such that during critical temperature periods the bird must have supplementary heat to maintain the proper body temperature. Bottorff[2] stated that if a day-old chick is subjected to a temperature of 78°F., the body temperature drops to 88°F. This can be detrimental to the health of the bird, if not fatal.

There are many ways and methods used to brood the chicks. One type of brooding equipment, the gas-fired infrared brooder, has become of interest in the South during the past few years. The brooding of chicks by this equipment is relatively new for this country, although the principle of using radiant energy for chick brooding is not. The use of infrared radiant energy from the electric heat lamp has been used many years as a means for brooding chicks. In 1943 Kennard and Chamberlin[3] of the Ohio Agricultural Experiment Station developed a unit using heat lamps as a source of energy. In 1944 Porter[4] suggested that heat lamps could be used as a source of energy for brooding. In 1955 Seeger and Oliver[5] and Baker and Bywaters[6] discussed the use of the heat bulbs as a source of infrared radiant energy for brooding chicks.

1/ Agricultural Engineer, Agricultural Engineering Research Division at State College, Miss.
2/ Bottorff, C. A. Relation of environmental temperature to nutrition and disease control. Paper presented at the Animal Nutrition Conference, Raleigh, N.C. 1961.
3/ Kennard, D. C., and Chamberlin, V. D. Homemade electric lamp brooder. Ohio Agr. Expt. Sta. Cir. 63. 1943.
4/ Porter, L. C. Lamps as a source of heat. Agr. Engin. 24:148. 1944.
5/ Seeger, K. C., and Oliver, J. H. Radiant energy chick brooding. Agr. Engin. 35: 278-80. 1951.
6/ Baker, V. H., and Bywaters, J. H. Brooding poultry with infrared energy. Agr. Engin. 35: 316-20. 1951.

Mitchell and Kelley[7] have determined the energy requirement of chicks weighing 1/2 to 7 pounds. By using data from Mitchell and Kelley, Seeger and Oliver[8] have made calculations on the energy level required for chicks from 1 day to 7 weeks old. The energy requirements for the chicks from 1- to 70-days old were fitted to the equation $E = 2.92 e^{0.0147 t}$, where E = BTU per 24 hours per degree below the critical temperature and t = age of birds in days. Baker and Bywaters[9] found that 1-week old chicks spread themselves out on the litter and acted comfortably in a range of radiant energy level from 0.12 to 0.40 watts per square inch (0.40 to 1.37 BTU per sq. in., hr.). The house temperature was not revealed.

Barott and Pringle [10] determined that the optimum temperature for brooding of chicks was to start off with a temperature of 94°F. and reduce it uniformly to 80° F. by the time the chicks were 18 days old. Beyond this age they found that the temperature could be further reduced by 1° per day until a temperature of 65°F. was reached. Huston[11] obtained as good, if not better, results in gain and feed conversion by starting the temperature at 85°F. and decreasing it 5°F. per week until 65°F. was reached. Applying the desired brooding temperature and the age of the birds to the above equation, the radiant energy requirement can be calculated. Table 1 gives some of these calculated values for different age birds and different house air temperatures.

7/ Mitchell, H. H., and Kelley, M. A. R. Estimated data on the energy, gaseous and water metabolism of poultry for use in planning ventilation of poultry houses. J. Agr. Res. 47 (10): 744. 1933.

8/ See footnote 5.

9/ See footnote 6.

10/ Barott, H. G., and Pringle, E. M. Energy and Gaseous metabolism of the chicken from hatch to maturity as affected by temperature. J. Nutrition 31 (1): 35-50. 1946.

11/ Huston, Till. The importance of an optimum environment for growing birds. Paper presented at the Georgia Annual Broiler Short Course, Athens, Ga. 1964.

Table 1. Calculated energy requirement for chicks 1 day to 6 weeks of age at various house air temperatures[1].

Age (days)	Recommended temperature	Energy requirement at indicated house air temperature of --				
		20°F.	30°F.	40°F.	50°F.	60°F.
	°F.	BTU/ sq. in., hr.	BTU/ sq. in., hr.	BTU/ sq. in., hr.	BTU/ sq. in., hr.	BTU/ sq. in, hr.
1	94	1.83	1.58	1.33	1.08	0.85
7	88.4	1.32	1.12	0.93	0.74	0.55
14	82.8	1.17	0.99	0.80	0.61	0.42
21	77	0.94	0.78	0.61	0.45	0.28
28	70	0.57	0.46	0.34	0.30	0.12
35	65	0.44	0.34	0.24	0.15	0.05
42	65	0.36	0.28	0.20	0.12	0.04

1/ Barott and Pringle's recommended brooder temperatures used as the critical temperature for the chicks, see text footnote 10.

Table 2. Projected area for one White Rock chick from 1 to 56 days of age.1/

Age of chick (days)	1	7	14	21	28	35	42	49	56
Projected area (sq. inches)	6	7	8	10	15	22	29	37	45

1/ From Baker and Bywaters, see text footnote 6.

The gas-fired infrared radiant brooder is altogether a different type of unit from the heat lamp, but it produces mainly an infrared radiant source of energy as does the heat lamp. It uses bottled or natural gas as a source of energy. The gas (liquefied petroleum or natural) is metered and mixed with air into a chamber. On the bottom side of the chamber is perforated ceramic or metal grate or generator. The pressure in the chamber forces the gas through the openings in the generator and the gas is ignited and burns close to the bottom surface of this perforated grate. The heat from combustion raises the surface temperature of the grate to approximately 1,700° F. Energy is then radiated from this surface down toward the floor and to the chicks. A small, rectangular-shaped hood is placed around the grate to direct the radiant energy down toward the floor (Fig. 1).

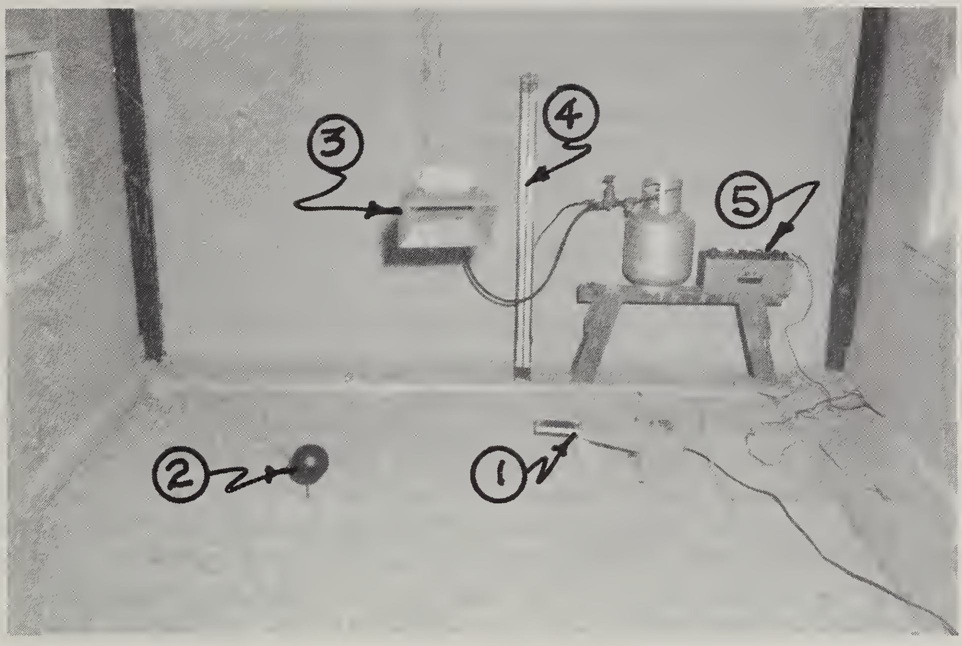


Figure 1. Evaluation test set up showing (1) total hemispherical radiometer, (2) black bulb thermometer, (3) brooder unit, (4) manometer and (5) potentiometer.

There is very little available data concerning the energy distribution and intensity pattern produced by these gas infrared brooders. The broiler grower has not had sufficient information for the best overall operation of the brooders. The brooder unit, in most instances, has been installed and placed at a certain height for baby chicks. It usually remained in this position during the entire brooding period and at all different house temperatures. Some producers have had trouble with their units not keeping the birds comfortable, especially during low temperatures. There have been differences of opinion as to this cause. Equipment dealers may blame low gas pressure, whereas gas dealers may criticize the equipment.

The energy intensity distribution and pattern for the gas-fired infrared radiant brooders are needed to give information necessary to regulate and adjust the brooders for different house temperatures, age of birds, and number of birds.

METHODS AND PROCEDURES

Laboratory tests consisted of determining the energy distribution and intensity pattern for three makes of the gas infrared radiant brooders. These patterns were determined for different heights of the brooders above

litter level, different angles of hang between the heated surface and a horizontal plane, and different operating gas pressures.

Brooder A had a perforated metal grate or generator, whereas brooders B and C had ceramic material for the generator. Brooders A and B had a fabricated metal chamber, whereas C had a cast metal one. Each of the brooder units was selected from the regular stock of the manufacturer, and each had approximately a 12,000 BTU per hour rating.

A wood frame made of 2- x 4-inch lumber turned on edge with dimensions of approximately 9 x 9 feet was used to hold wood shaving litter. A grid made of smooth wire spaced 18 inches on center both ways was placed over the shavings in this frame. The point where the wires crossed was used as the station to measure the radiant energy intensity. A total hemispherical radiometer was used to measure the radiant energy at these stations. A precision potentiometer was used to measure the data required from the sensing plate of the radiometer. The brooder was suspended over the center of the litter area so that a line perpendicular to the center of its heated surface would pass through the center measuring station. The brooders could be raised or lowered as necessary. A manometer and regulating valves were placed in the gas line to determine and maintain an accurate operating gas pressure.

Brooder heights of 30, 36, 42, and 48 inches were tested on all three makes of brooders and a 54-inch height was also tested on one make. The 54-inch height was tested because the manufacturer of this particular unit recommended that the brooder be hung at a height of 48 to 54 inches above the chicks. Some of the operators in the field were using this height.

Operating gas pressures of 8, 10, 12, 14, and 16 inches of water column were tested on one make of brooder. It was decided after the test on the first brooder that a pressure of 8 and 12 inches only would be used on the other two makes. These two brooders would not operate efficiently above the 12-inch water-column pressure.

A black globe thermometer was also placed under the brooder to determine how the globe temperature varied with height and pressure.

The radiometer reading was taken in each position with the brooder off and then again when the brooder was turned on with each of the gas pressures. Enough time was allowed to get a stabilized reading from the potentiometer between each different reading. This procedure was followed for each height and each angle of hang tested. The difference in the amount of radiant energy intercepted on the sensing plate with the brooder on and with it off was assumed to be energy produced by the brooder.

The radiant energy value was calculated for each test station and plotted on cross section paper. Lines connecting points of equal values of radiant energy of 0.25, 0.50, 1.00, and 1.50 BTU/sq. in., hr. were drawn. The area

within the boundary of each of these lines was determined by use of a planimeter. (Fig. 2)

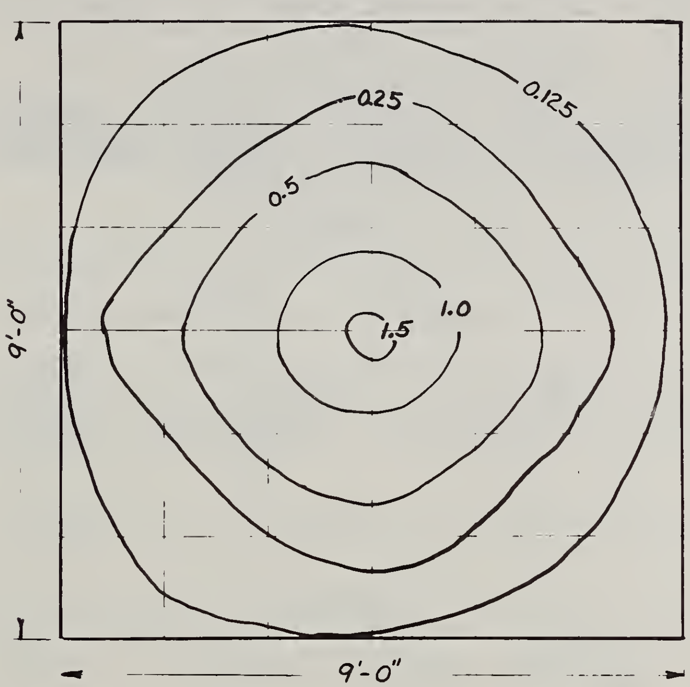


Figure 2. Iso-radiant energy lines for Brooder C (units are in BTU per Sq. in., hr.)

RESULTS AND DISCUSSION

The maximum radiant intensity occurred at the station located on the litter directly under the center of the brooder for each unit. This intensity varied with the height of the brooder above the litter and also between brooders (table 3.).

Table 3. Radiant energy intensity at a point directly under the brooder with 12 inches of water column gas pressure and 30° angle of hang of the brooder.

Brooder number	Height of brooder above litter				
	30 in.	36 in.	42 in.	48 in.	54 in.
	BTU/sq. in., hr.	BTU/sq. in., hr.	BTU/sq. in., hr.	BTU/sq. in., hr.	BTU/sq. in., hr.
A	1.46	1.06	0.77	0.60	--
B	3.57	2.01	1.47	1.31	--
C	2.43	1.67	1.16	0.98	0.83[1/]

1/ Only one tested at this height.

Table 4 gives the area within the boundary of the different iso-radiant energy lines for Brooders A, B, and C. The areas of the higher intensities decreased rapidly with an increase in height of the unit. The areas of the low intensities of 0.25 and 0.50 BTU per sq. in., hr. did not decrease so rapidly, and, in some cases, the area increased as the height of the brooder was increased.

The increase in floor area shown at these lower intensities would be desirable. However, according to data in table 1, these low radiant energy levels would only be adequate for older birds or fairly high house temperatures. As the bird gets older, it requires more floor area; therefore, a larger comfort zone.

Table 4. Floor area bounded by iso-radiant energy lines for brooders at 12 inches of water column gas pressure and at manufacturer's recommended angle of hang.

Radiant energy level	Bounded floor area — Height of brooder above litter				
	30 in.	36 in.	42 in.	48 in.	54 in.
BTU/sq. in., hr.	Sq. in.	Sq. in.	Sq. in.	Sq. in.	Sq. in.
BROODER A					
0.25	5,145	4,306	5,178	4,915	1/
0.50	2,569	1,779	1,429	574	
1.00	645	16	0	0	
1.50	0	0	0	0	
BROODER B					
0.25	6,584	7,617	8,349	9,500	1/
0.50	4,316	3,862	4,225	4,409	
1.00	2,391	1,678	1,037	1,105	
1.50	1,157	370	0	0	
BROODER C					
0.25	4,506	4,879	4,938	4,983	4,944
0.50	2,281	2,615	2,371	1,818	1,944
1.00	1,076	710	113	0	0
1.50	550	52	0	0	0

1/ These brooders were not tested at this height.

The angle of hang of the brooder had some, but not a great, effect on the area bounded by the different iso-radiant energy lines (table 5). The 15° angle gave a little larger area than the 30° angle on the low energy level, on two of the brooders. The manufacturers of brooders A and B recommended that their units be hung with approximately a 30° angle, whereas those of brooder C recommended their units be hung with approximately 15° angle. No trouble was experienced with the operation of any of the brooders at either angle of hang. A long period of operation might have some influence on the operation.

Table 5. Floor area bounded by iso-radiant energy lines with 15° and 30° angles with horizontal hang and at a 36-inch height.

Brooder	Angle of hang	Maximum intensity	Floor area bounded by radiant energy intensities of-- 0.25	0.50	1.00	1.50
			BTU/sq. in., hr.			
	Degrees	BTU/sq. in., hr.	Sq. in.	Sq. in.	Sq. in.	Sq. in.
C	15	1.67	4,879	2,615	710	52
	30	1.33	4,481	1,912	337	0
B	15	1.99	7,523	4,445	2,022	570
	30	2.01	7,617	3,862	1,678	370

The operating gas pressure definitely had some influence on the radiant energy intensity and also on the area covered by the iso-radiant energy lines (table 6). The brooders should not be operated at too high a gas pressure, because if this happens the flame will jump away from the lower surface of the generator grate and it will not heat the grate to as high a temperature as that given by lower gas pressures; therefore, less radiant energy will be transmitted by the unit.

Table 6. Effects of the operating gas pressure of the brooders on the floor area bounded by various iso-radiant energy lines at a brooder height of 36 inches and at the angle of hang recommended by the manufacturers.

Operating pressure	Maximum intensity	Floor area bounded by radiant energy level of --			
		0.25 BTU/sq. in., hr.	0.50 BTU/sq. in., hr.	1.00 BTU/sq. in., hr.	1.50 BTU/sq. in., hr.
Water Column Inches	BTU/sq. in., hr.	Sq. in.	Sq. in.	Sq. in.	Sq. in.
BROODER A					
8	0.90	3,282	706	0	0
12	1.06	4,306	1,779	16	0
16	1.21	5,330	2,475	327	0
BROODER B					
8	1.59	6,548	3,629	1,001	32
12	2.01	7,617	3,862	1,678	370
BROODER C					
8	1.04	3,451	881	6	0
12	1.33	4,879	2,615	710	52

Figures 3, 4, and 5 show the radiant energy distribution patterns for the brooders in planes both crosswise and lengthwise through the center of the brooder unit. At the 30-inch height, brooders B and C (especially B) had a very high peak directly under the unit, but the energy level decreased rapidly as the distance from the center of the unit increased. This high peak decreased as the height of the brooder was increased. The brooders made a similar distribution pattern from front to rear as they did from side to side. Except for brooder B, increased height of the brooder did not greatly affect the width of spread of the pattern. For brooder B the intensity of the radiant energy was about the same or the distribution lines crossed for all heights at a distance of approximately 27 to 28 inches from the center of the brooder. On brooders A and C this occurred either at a distance of approximately 48 inches from the center or it did not occur. If it did occur, it was at a fairly low intensity level. Except for brooder B increasing the height of the brooder would not increase the size of the comfort zone for either small or large birds except for the area directly under the brooder.

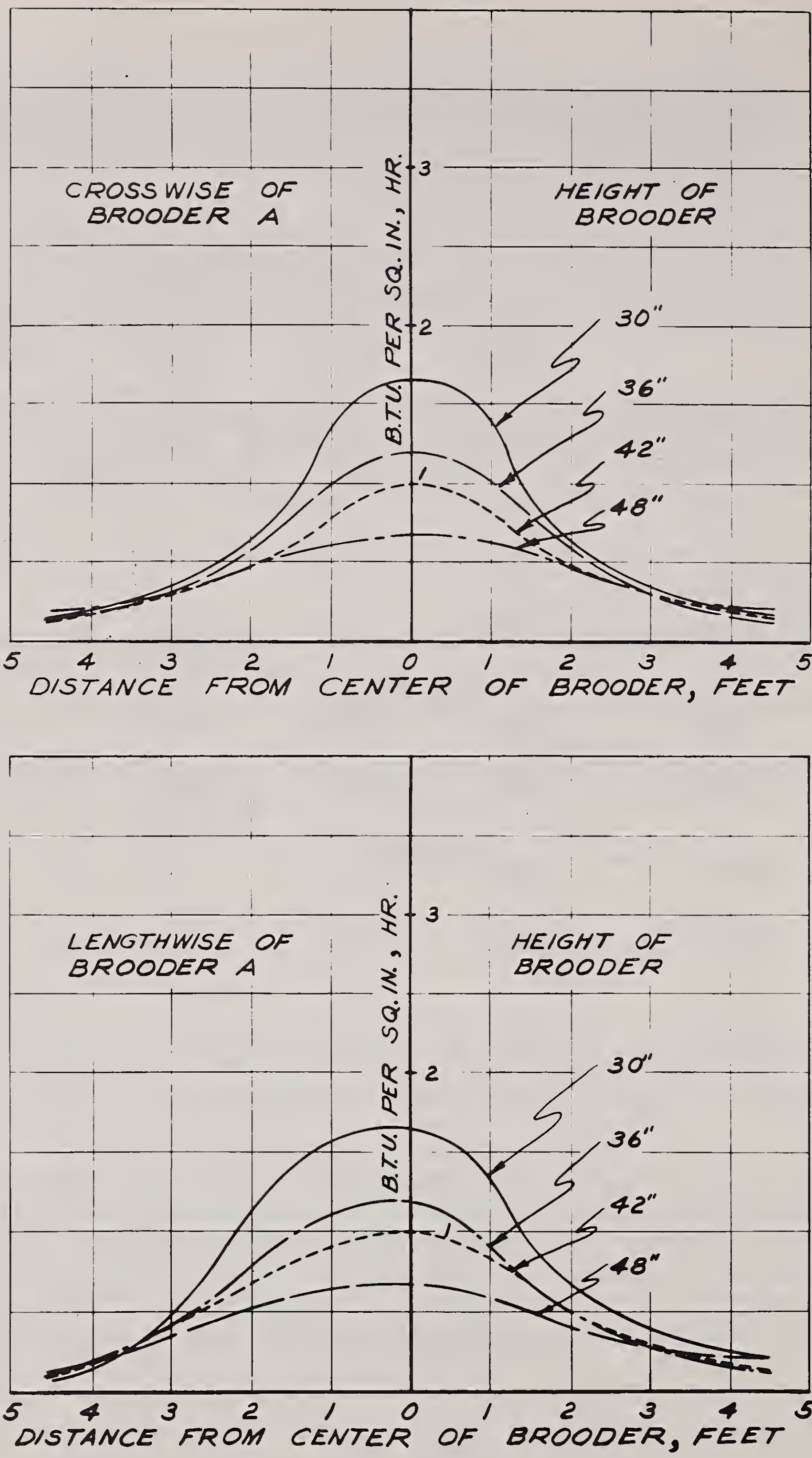


Figure 3. Radiant energy distribution pattern for Brooder A in planes crosswise and lengthwise of brooder.

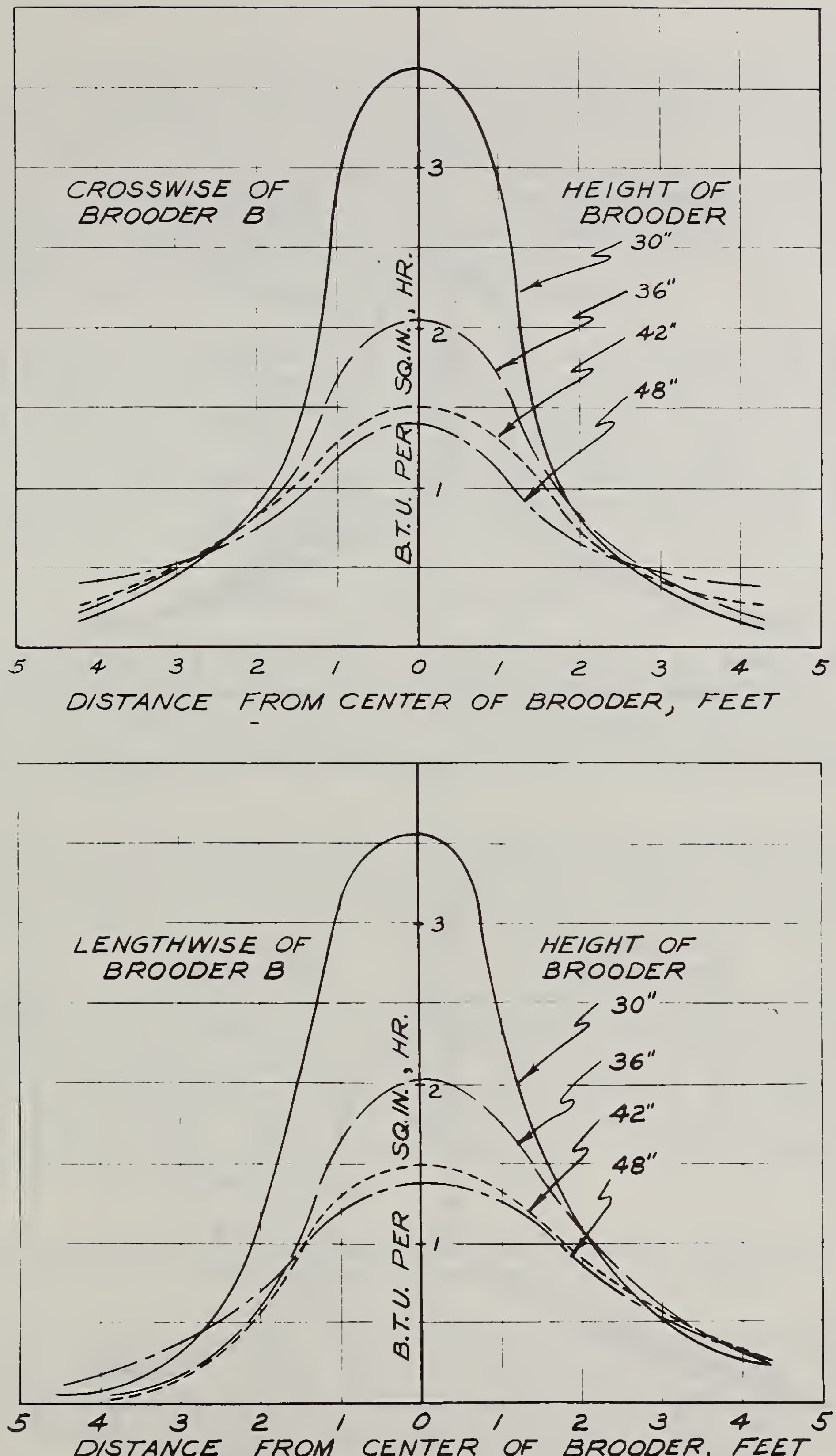
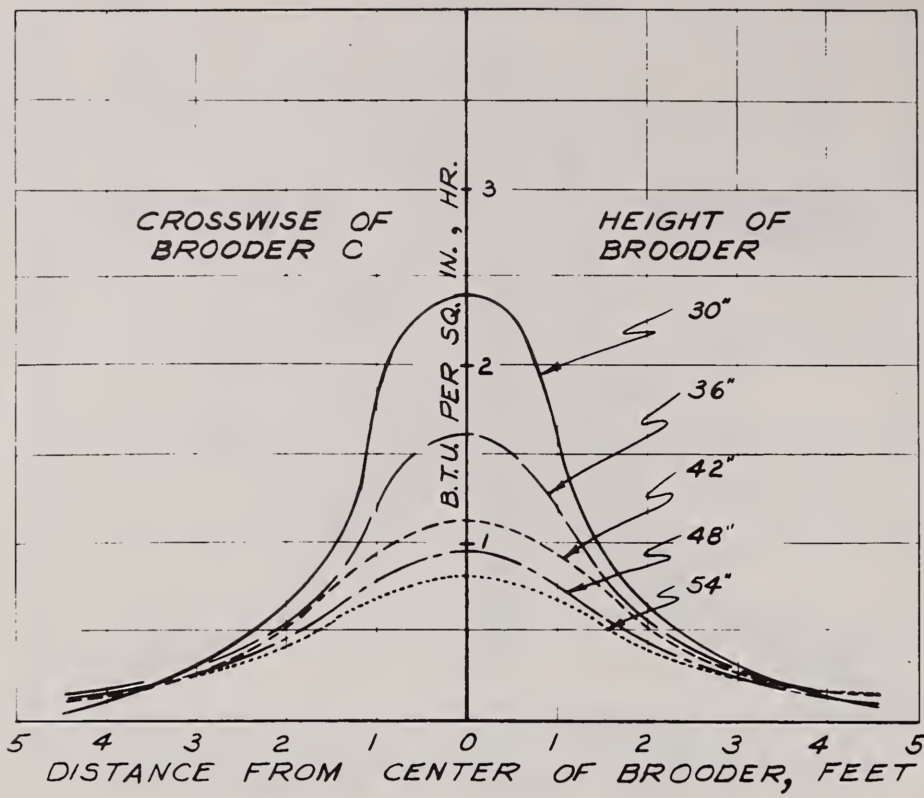


Figure 4. Radiant energy distribution pattern for Brooder B in planes crosswise and lengthwise of brooder.



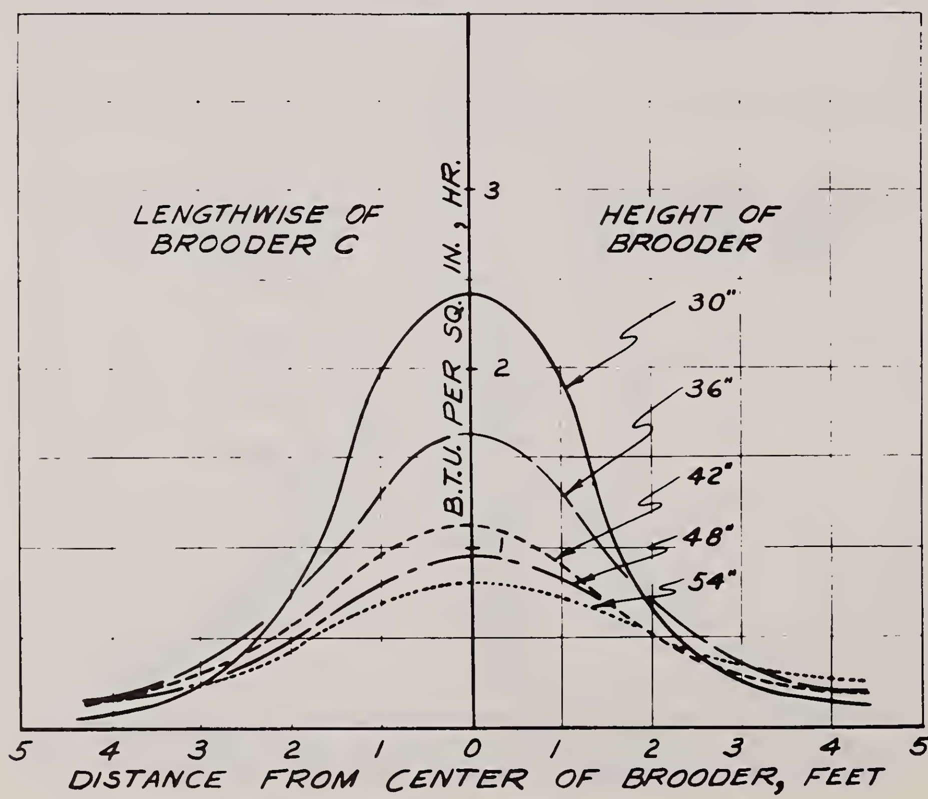


Figure 5. Radiant energy distribution pattern for Brooder C in planes crosswise and lengthwise of brooder.

Baker and Bywaters 12/ stated that when radiant heat lamps are used for brooding, about 50 percent of chicks stay under the brooder and 50 percent are out eating. This will depend on the temperature of air in the house. Observations were made in houses with the gas infrared brooder and with an air temperature of approximately 30° to 35° F. At these temperatures approximately 80 to 100 percent of the birds would be under the brooder. So it would be safe to allow for 50 percent for house temperatures of 45° F. and above and about 75 to 80 percent for temperatures less than 40° F.

The percentage of the total heat given off from the gas infrared brooder as radiant energy was not determined. Brooder houses with this type of brooder have been kept 5° to 10° F. warmer at night during cool weather than the same type house with the large canopy gas brooder. Due to this and the fact that a large quantity of hot air was sensed when a hand was held above the brooder unit when it was operating, a substantial percentage of the heat was apparently given off by convection.

SUMMARY AND CONCLUSIONS

The three brooders tested showed a wide variation in the intensity and spread of radiated radiant energy when operated under comparable conditions. According to the established radiant energy requirement for chicks, one of these brooders would not be expected to provide satisfactory service during low temperature periods.

The height of the brooder above the floor had an important effect on the intensity of radiant energy immediately under the brooder unit, but this effect almost disappeared as the distance from the center of the brooder increased.

The height the brooder should be placed when the chicks are young will vary among manufacturers, but the most desirable height seems to be between 30 and 36 inches for house temperatures of approximately 30° to 35° F. The brooder should be raised to 42 to 48 inches in height by the time the birds are 28 to 30 days of age. This will reduce the intensity of the radiant energy directly under the brooder unit; therefore, make this area more comfortable for the birds.

The angle the brooder made with a horizontal plane had very little effect on the intensity and area of the radiant energy pattern.

The operating gas pressure affected the intensity and area covered by the different iso-radiant energy lines. Precautions should be taken to use correct size of pipe, regulating equipment, and fuel to maintain the gas pressure as recommended by the manufacturer of the brooder unit.

Examining the radiant energy requirements for birds and the distribution pattern of the gas infrared brooders provides good reasons for the birds piling up or forming a donut-shaped ring under the brooder units. The

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brooder might be of a make or placed at such height that there is very little if any comfort zone for the birds. In this case the birds will keep piling up to try to find a comfortable place. The brooder might be at a low height; therefore, produce a very high intensity of radiant energy directly under the brooder, and the birds would probably form a donut-shaped ring around the brooder.